Achieving Diffraction-limited EUV Aerial Image Microscopy

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The SEMATECH Berkeley Actinic Inspection Tool (AIT) is a prototype EUV aerial image microscope dedicated to EUVL mask inspection

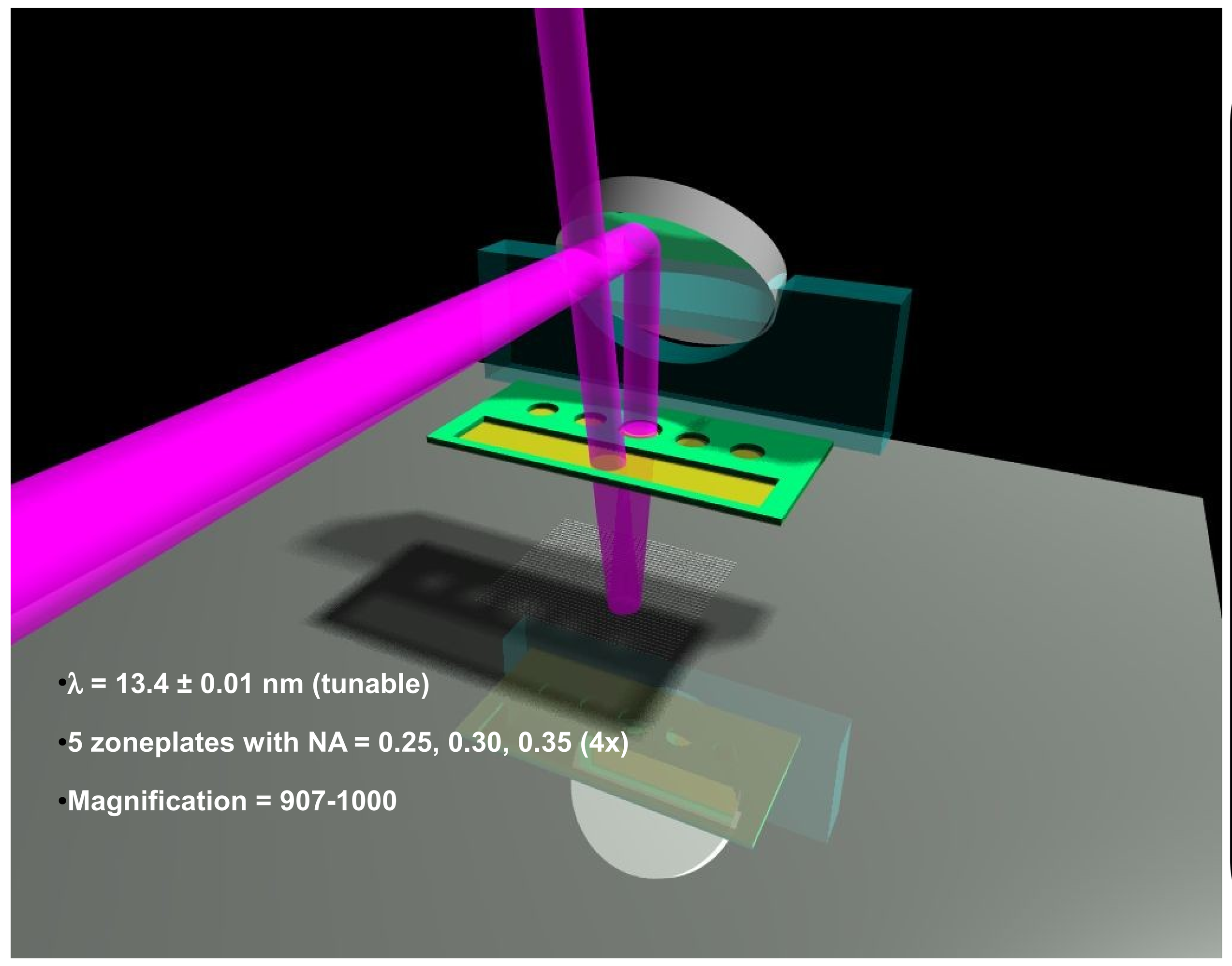
ABSTRACT

The AIT has a flexible design and light path that enables the use of zoneplates with different optical properties. However, the drawback of such flexibility is the need for frequent, careful, fine alignment to maintain optimal performance and minimize alignment-dependent aberrations. In order to improve the alignment procedures, and thus the performance and stability of the tool, we have developed a detailed ray-tracing model of the optical system, and image analysis tools that provide quantitative aberration feedback. Feedback enables us to correct misalignments with greater confidence, and to reach closer to the goal of diffraction-limited performance.

Advances in system alignment, and recent upgrades that include new zoneplates and a higher resolution CCD camera enable the AIT to achieve contrast values above 75% at 100-nm (mask) linewidth. New user-selectable zoneplates have higher magnification ratios than before, and 4x NA values from 0.25 to 0.35.

GOALS

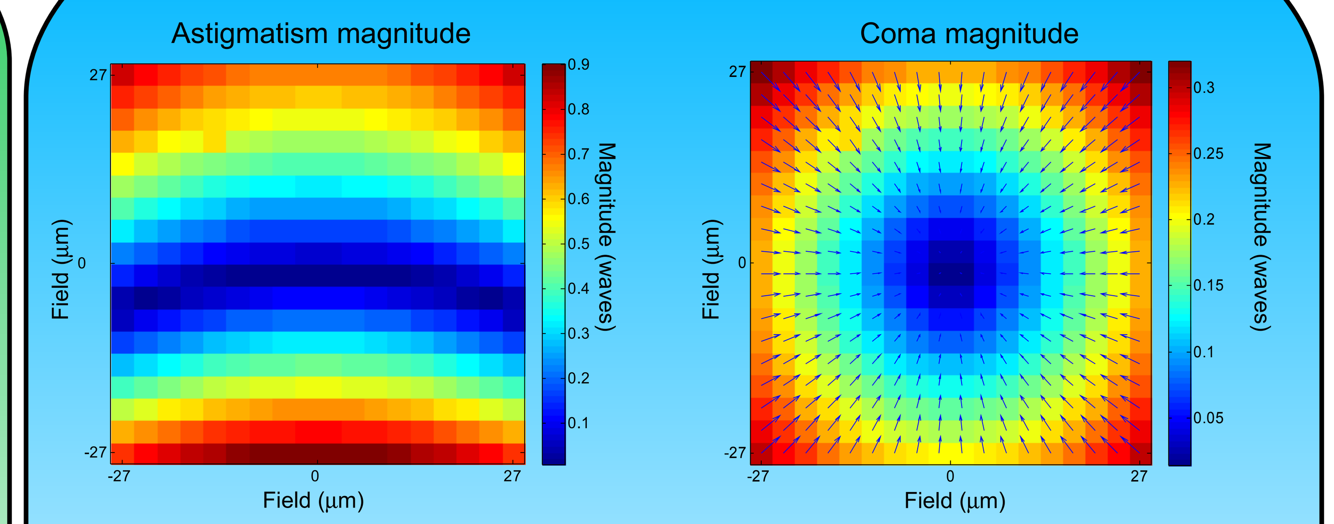
- Improving the image quality
- Developing a quick and reliable alignment procedure
- Quantifying the optical performances of the system in terms of aberrations magnitude



Methods

- Creation of an optical model of the AIT with ZEMAX® ray-tracing software, taking into account the off-axis zoneplate geometry
- Predict the aberrations across the field of view
- Use through-focus images of contacts as input for the analysis
- Selection of contacts in the region of interest
- Processing of the images and comparison with theoretical model to retrieve the aberration coefficients

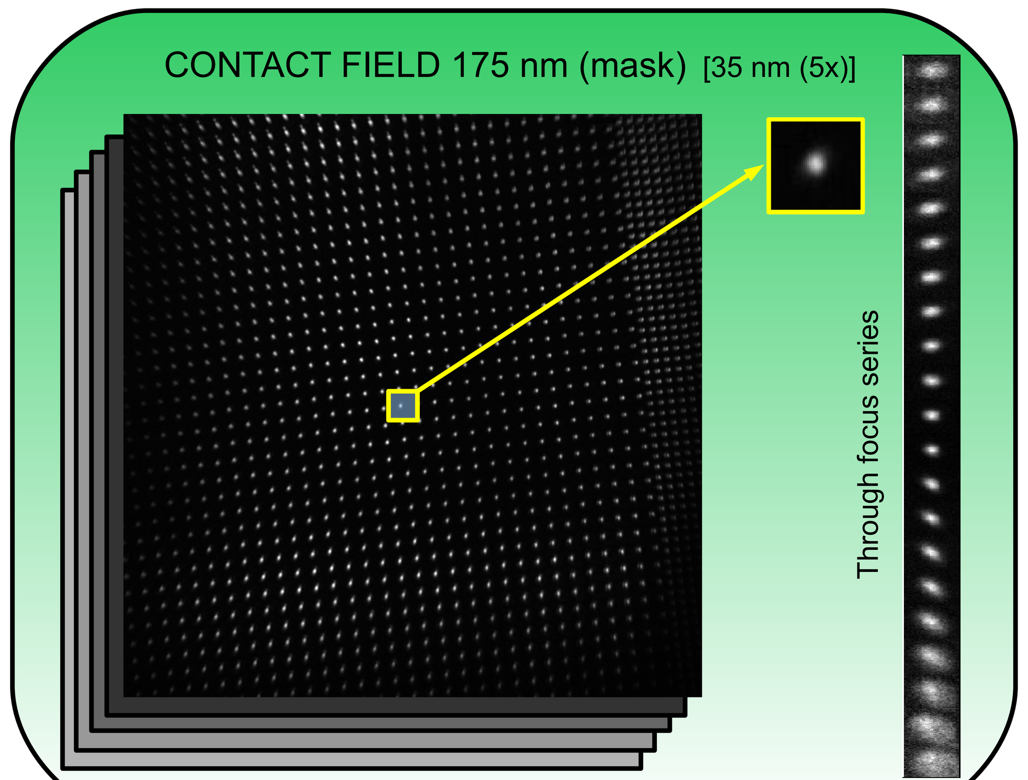
Predicted aberrations



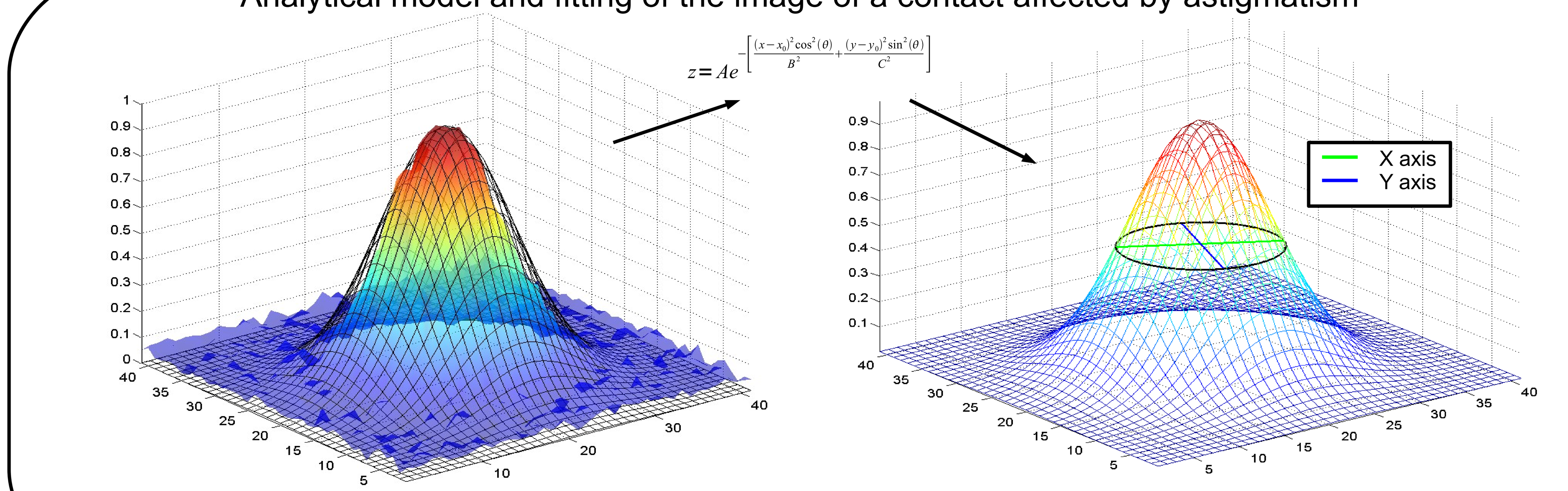
Astigmatism is the main aberration of the system.

- The off axis zoneplates used in the AIT have a diameter of ~100 μm and in the center of their field of view there is a zero-aberration sweet spot
- The off axis design generates a tilted focal plain resulting in a defocus term along the y direction
- Other aberrations expected peak to valley contribution across the field :

Coma	0.4	waves
Spherical	0.004	waves

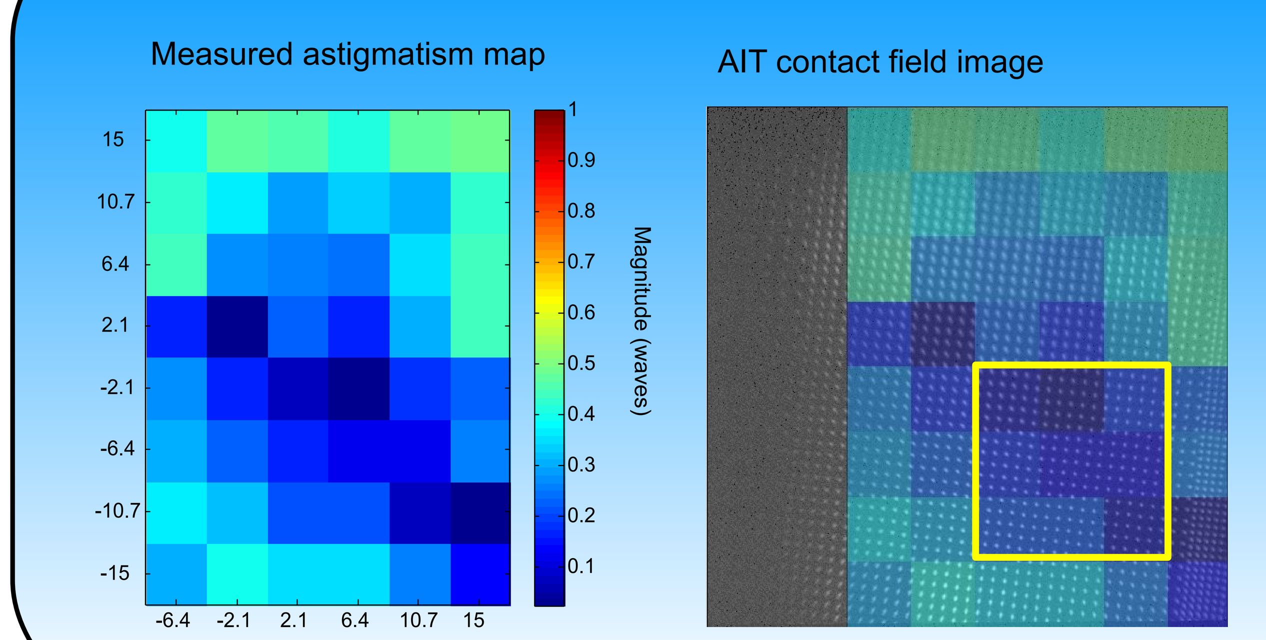


Analytical model and fitting of the image of a contact affected by astigmatism



We fitted a double Gaussian function to the image of a single contact and we estimated the elongation of the two axis of its elliptical shape. Analyzing the evolution of these elongations in a through focus series we obtained a measure of the astigmatic displacement in several regions of the field of view

Evaluation of "aberration free" field of view

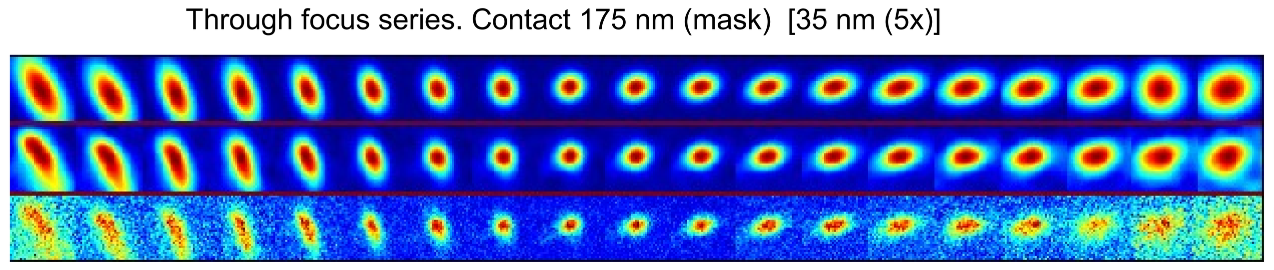


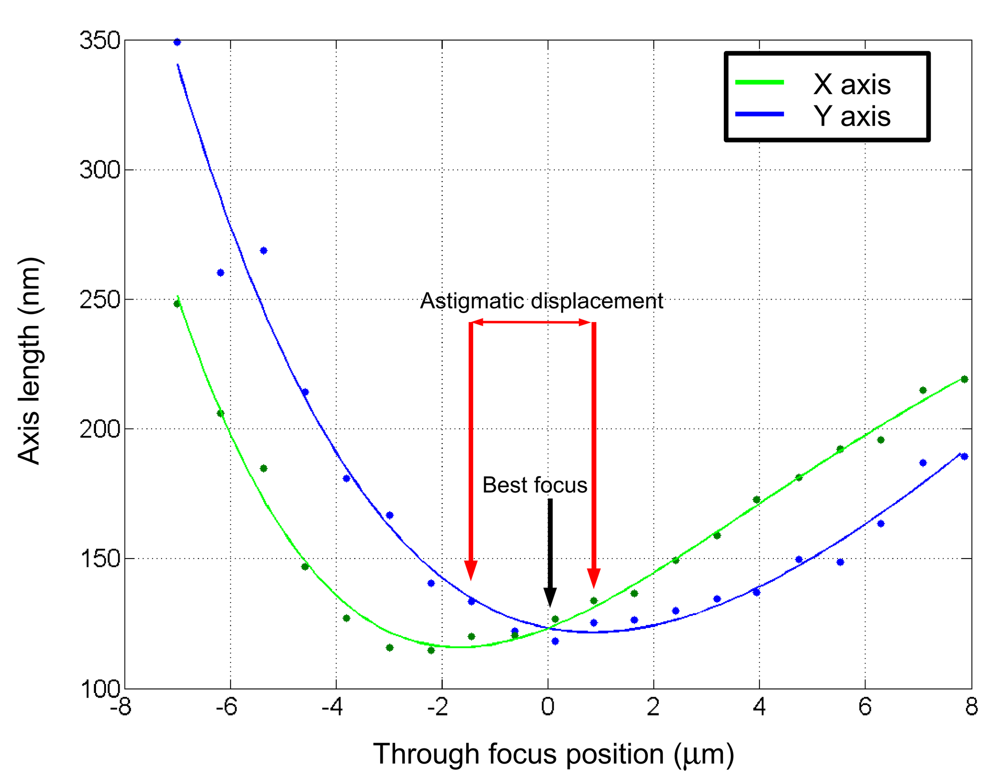
In the selected region the astigmatism magnitude is limited to 0.23 λ rms

The "sweet spot" is 13 mm wide and is the region used to extract data for quantitative analysis

APRIL 2008 DATA (before alignment improvement)

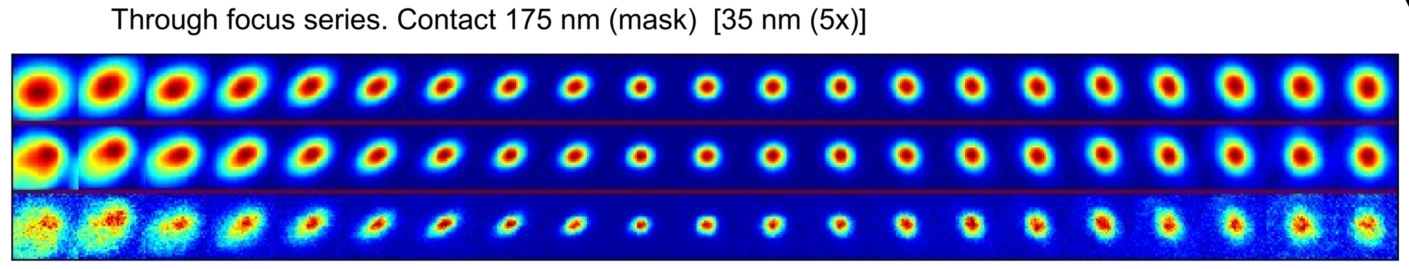
Through focus series. Contact 175 nm (mask) [35 nm (5x)]



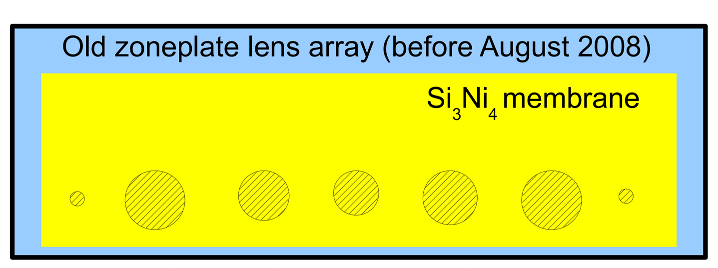


AUGUST 2008 DATA (after alignment improvement)

Through focus series. Contact 175 nm (mask) [35 nm (5x)]

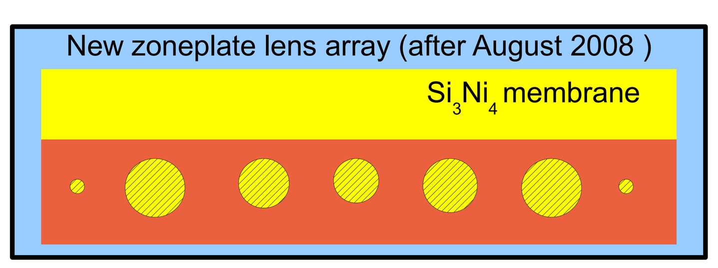


Old zoneplate lens array (before August 2008)



4X NA:	0.25	0.25	0.30	0.25	0.25
f (μm):	1000	850	750	750	750
mag:	680x	800x	906x	906x	906x

New zoneplate lens array (after August 2008)



4X NA:	0.25	0.25	0.25	0.30	0.35
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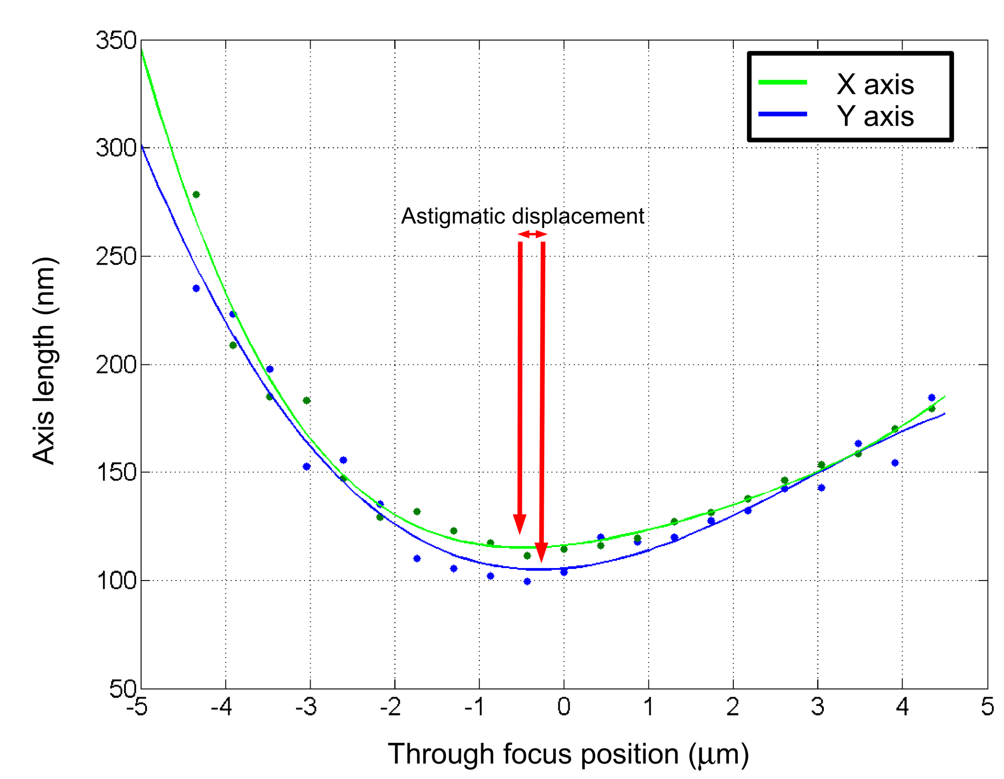

CONCLUSIONS

- We devised a method to estimate the astigmatism magnitude across the field from the analysis of contact fields images
- We are able to quantify the extension of the "aberration free" area in the field of view of the microscope
- We reduced the astigmatism magnitude in the central part of the field from 0.23 λ rms to 0.08 λ rms

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Intel
Ted Liang